Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Accelerator Division All-hands meeting

Lindgren

November 12, 2018

Agenda

- Kickoff – Mike
- LBNF - Rob
- Mu2e - Ron
- NOvA - Peter/Tricia
- MINERvA - Laura/Debbie
- MicroBooNE - Sam/Bonnie
- g-2 - Chris/Mark
- test beam - Mandy
- IOTA/FAST - Sasha/Sergei
- Questions – all

Top 5 takeaways from director's Oct. 15 all-hands meeting

- LBNF far site and US-DUNE far detector must be baselined (receive CD-2) approval) in 2019.
  - Full pre-excavation construction work expected to begin in December in South Dakota.
  - Outstanding technical performance by ProtoDUNE at CERN, which recorded its first charged particle tracks and has met all technical specifications. Congratulations to the collaboration.

- PIP-II has achieved CD-1 and must be baselined (receive CD-2 approval) in 2019.
  - The project continues to receive broad support and maintain excellent technical progress.
  - Strong engagement with international partners continues.

Top 5 takeaways from director's Oct. 15 all-hands meeting

- LCLS-II cryomodule (CM) transportation issues are being addressed by a multi-lab team.
  - A solution is close and plan is to begin transporting CMs to SLAC in November.
  - CM assembly is on schedule, with all CMs exceeding specifications.

- Mu2e transport solenoid first production module coil successfully tested.
  - Continue to address challenges with Detector and Production solenoidal coil winding that is impacting schedule.

- LHC CMS HL-LHC detector upgrade project advancing toward CD-1 next spring and superconducting quadrupole magnet fabrication progressing to CD-2.

AD Top Five

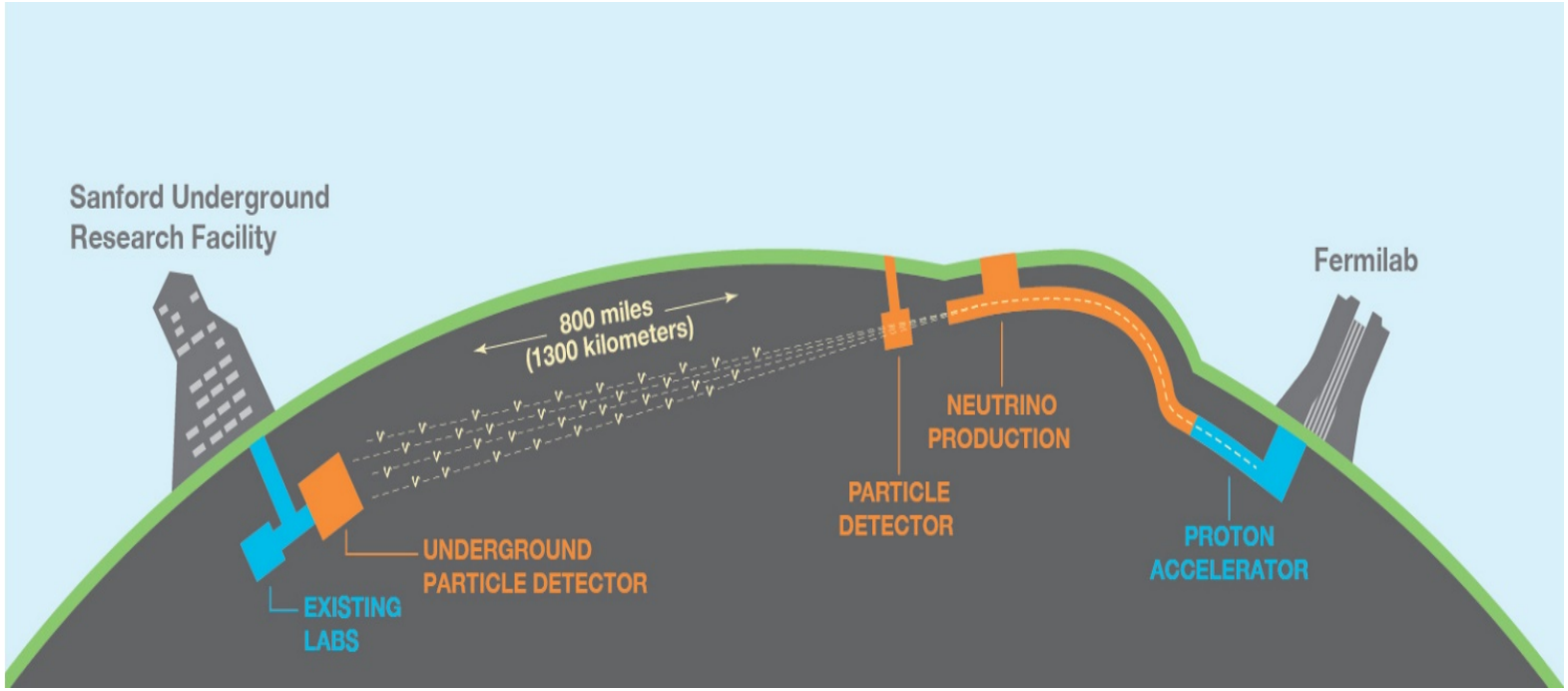
- We have a very large work scope and we must ensure that it doesn't impact our commitment to performing our work safely.
- Work to ensure PIP-II is ready to be baselined in 2019 and that the LBNF beamline makes progress towards baseline.
- Deliver on promised Accelerator Operations - Priorities:
  - NuMI at 700 kW (630 kW with SY120)
  - Muon at 1E12 protons on target (when g-2 taking physics data)
  - SY120 gets 10% of the timeline when test beam requested
  - BNB baseline + opportunistic
- Do our part to keep Mu2e on track to completion
- Complete the modernization review

New arrivals

- Jakob Schaeffer – Operator – Operations
- Pierrick Hanlet - Applic Dev & Sys Analyst - Controls
- Matilda Mwaniki – Operator – Operations
- Matt Dalton - Technician - Mechanical Support
- George Lolov – Engineer - Target
- Keymonty Bullock – Operator - Operations
- Dan Lambert – Senior Technician - Mechanical Support
- Robert Ridgway – Engineer - Mechanical Support
- Clay Leonard – Technician - Target
- Patrick Dowdle – Operator - Operations
- Tyrone Evans – Technician - E/E Support
- Ryan Crawford – Staff Engineer - E/E Support

Long Baseline Neutrino Facility (LBNF) Project

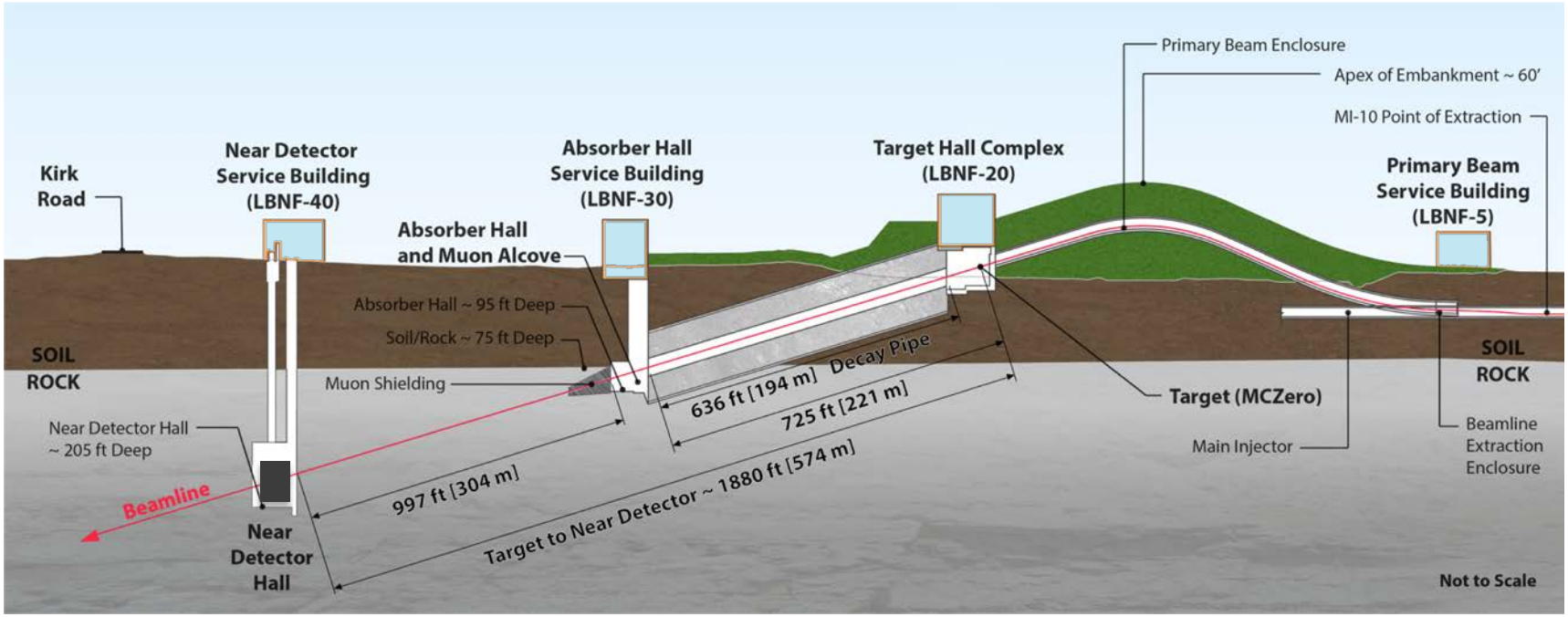
World-Class Facility supporting World-Class Experiment



- The **Deep Underground Neutrino Experiment** will be a game-changing **experiment** for neutrino science, potentially transforming our understanding of why the universe exists as it does.
- The **Long-Baseline Neutrino Facility** is the **infrastructure** necessary to send a powerful beam of neutrinos 800 miles through the earth, and measure them deep underground at South Dakota's Sanford Underground Research Facility.

DUNE/LBNF project will be the **first internationally conceived, constructed, and operated mega-science project** hosted by the Department of Energy in the U.S.

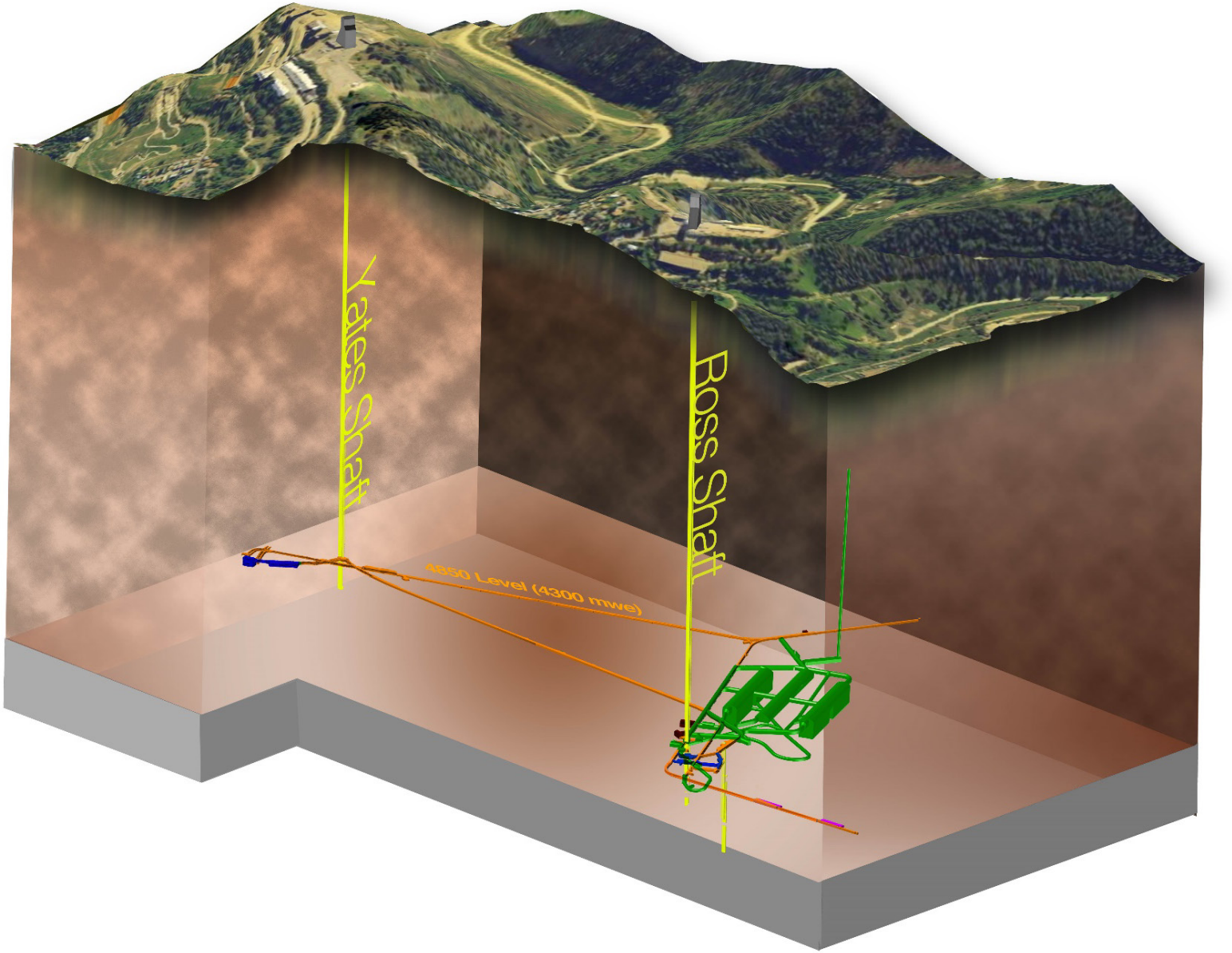
Overview - “Near Site” – LBNF/DUNE at Fermilab



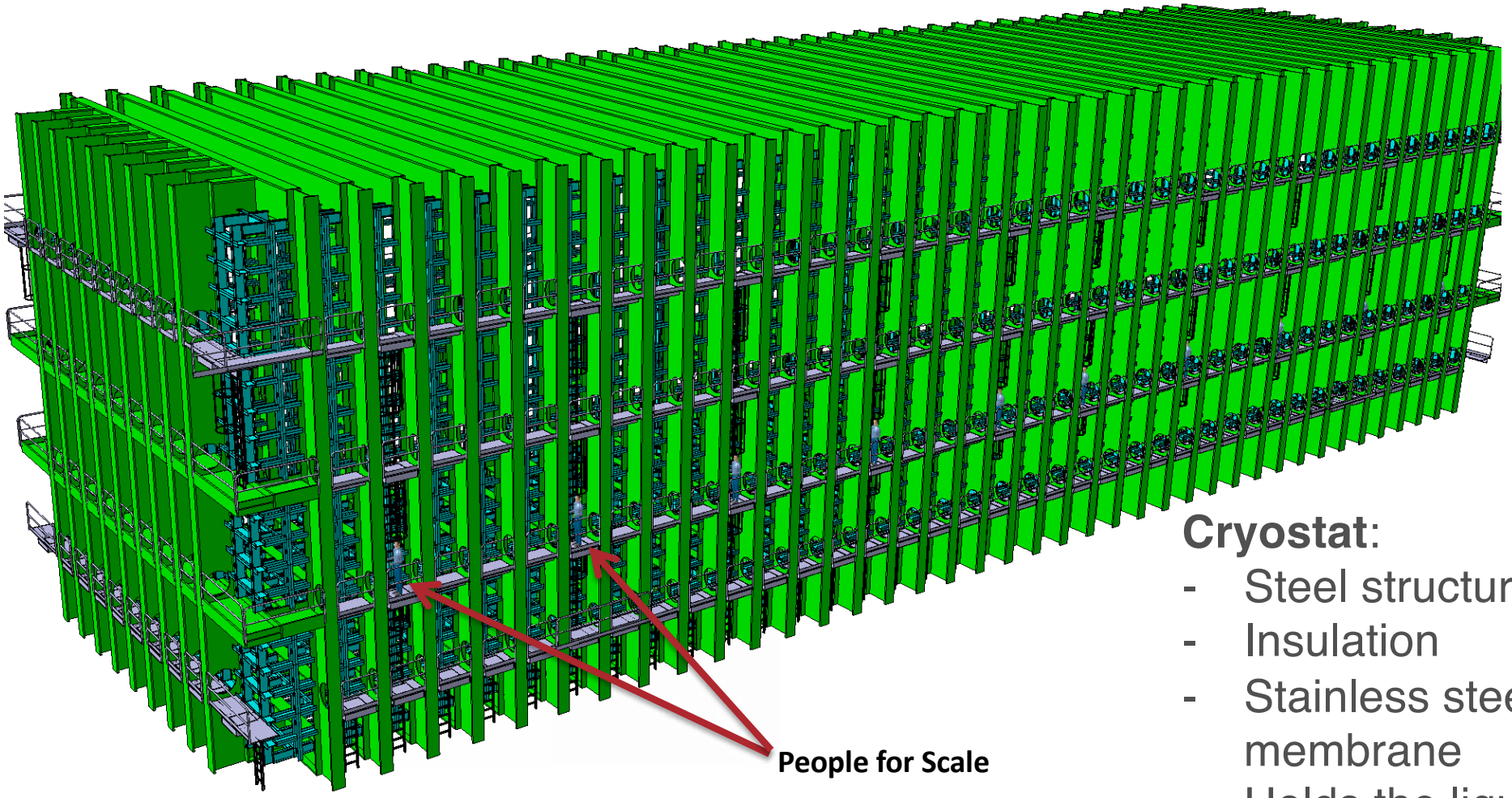
- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to SURF
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility

Optimized beamline provides significantly more physics reach over NUMI based reference design

Far Site - Phases of Work and Status



Free-Standing Steel Cryostat Design



Cryostat:

- Steel structure
- Insulation
- Stainless steel membrane
- Holds the liquid argon

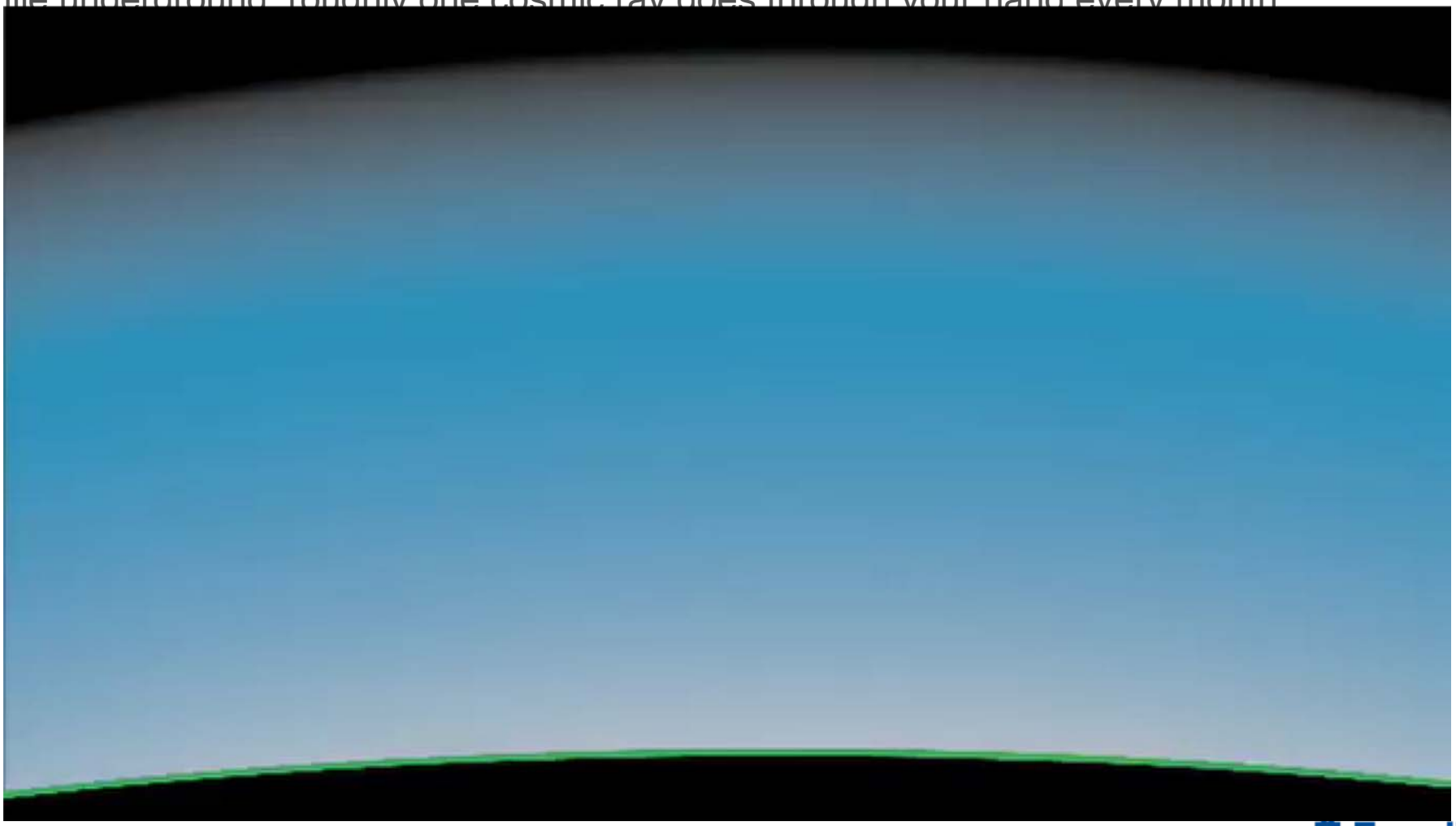
External Dimensions
62.7’ W x 59’ H x 216.5’ L (19.1m W x 18.0m H x 66.0m L)

Why underground? It's a "quiet" place.

The Earth is constantly bombarded by cosmic rays.

On the surface, you have about three cosmic rays go through your hand every second

A mile underground, roughly one cosmic ray goes through your hand every month



Concluding Remarks

International Project Milestones	Date	LBNF/DUNE-US working schedule date
Start Main Cavern Excavation	2019	2019
Start Detector #1 Installation	2022	2023
Beam on with two detectors	2026	2029

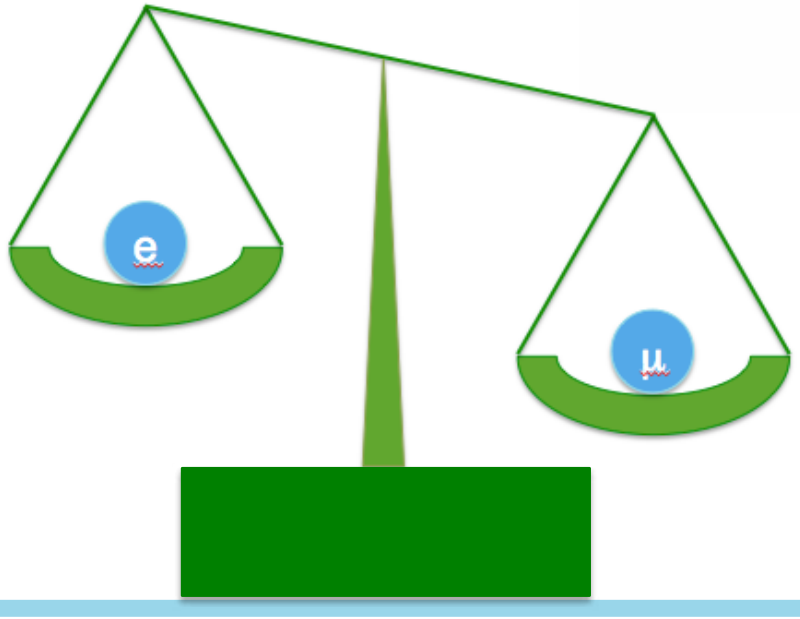
- Accelerator Division is responsible for most facets of the beamline project
- AD is the best organization in the world to do execute it!
- We have the right team engaged
- We have a very aggressive schedule – CD2 in October 2019
- Will need help from everyone in AD to backfill responsibilities of people on our team so they can focus on design maturation

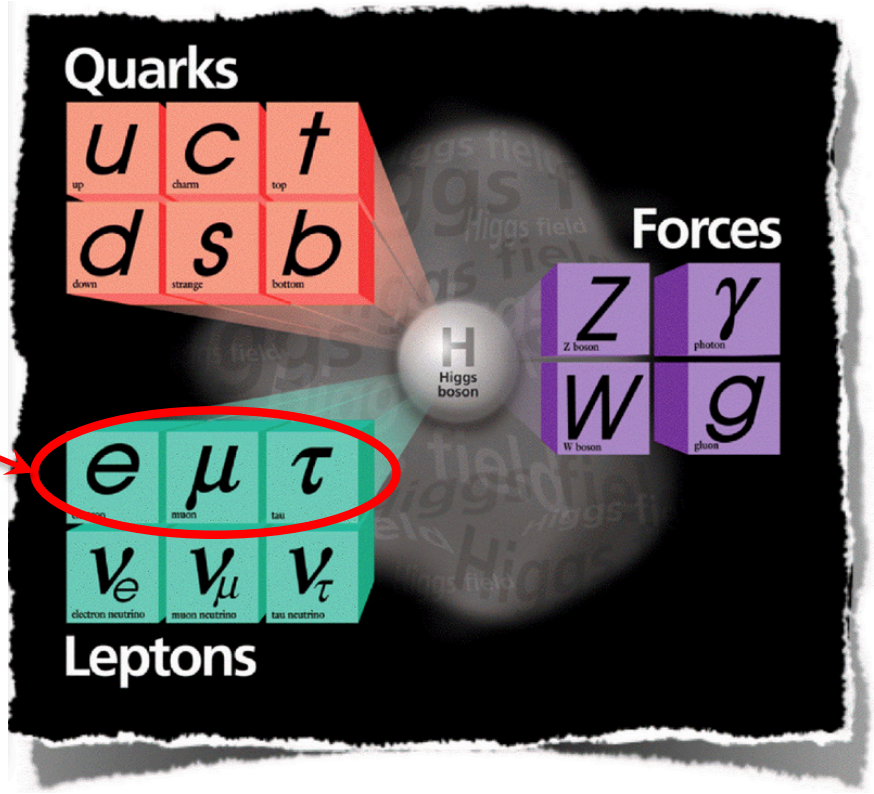
Mu2e Project

Mu2e

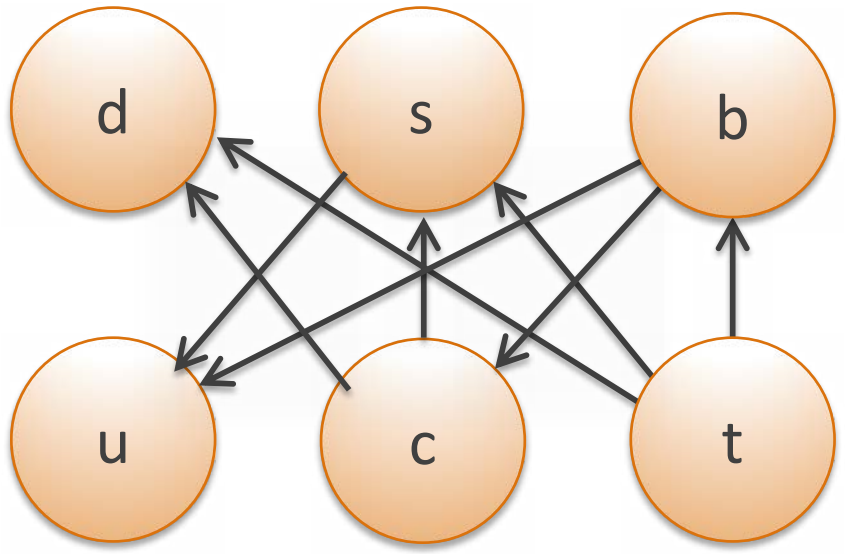
- Mu2e stands for *Muon to Electron.* Mu2e is searching for muons that convert to electrons in the field of a nucleus.

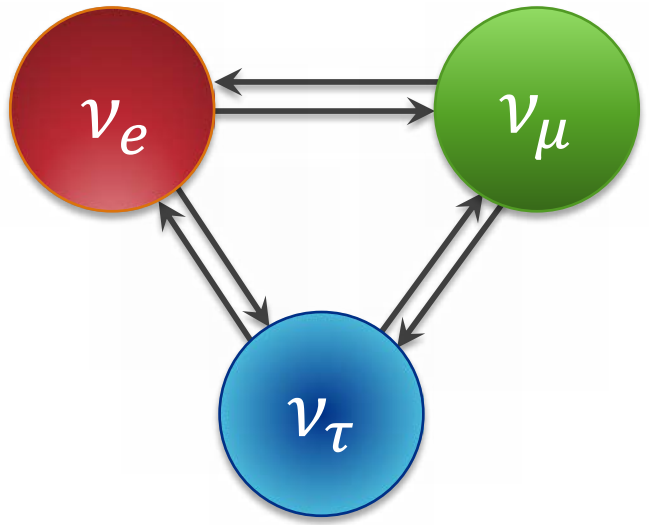
- Electrons and muons both belong to a category of particles called *Leptons.*





- Quarks can change from one type to another
- Neutrinos can change from one type to another (oscillations)
- Mu2e is looking for charged leptons to change from one type to another.

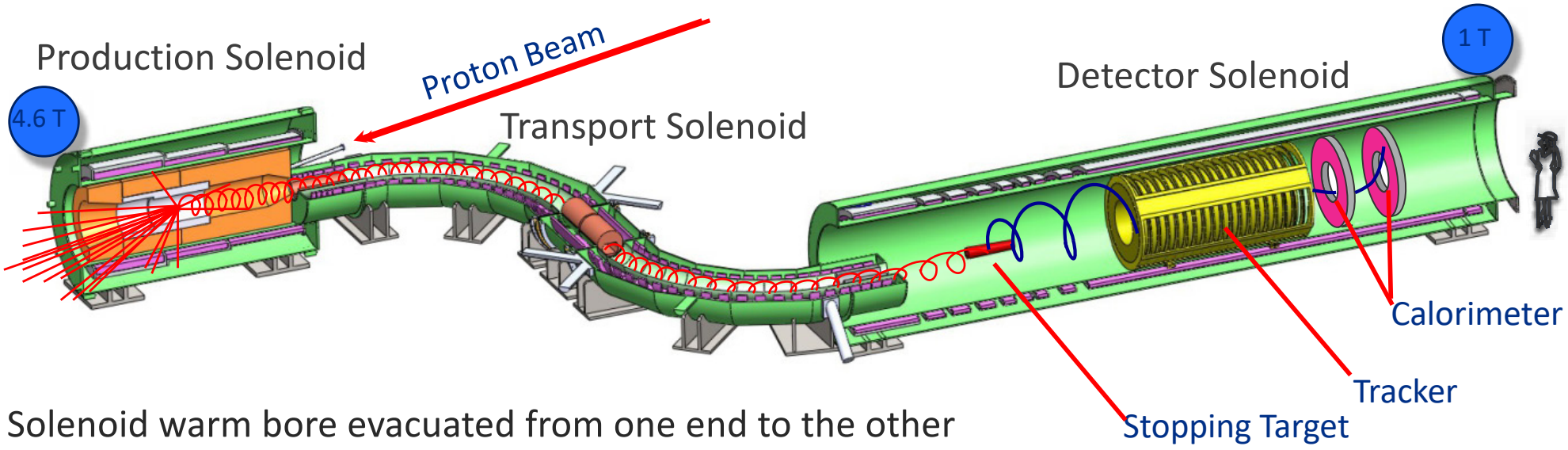




Mu2e Project Scope

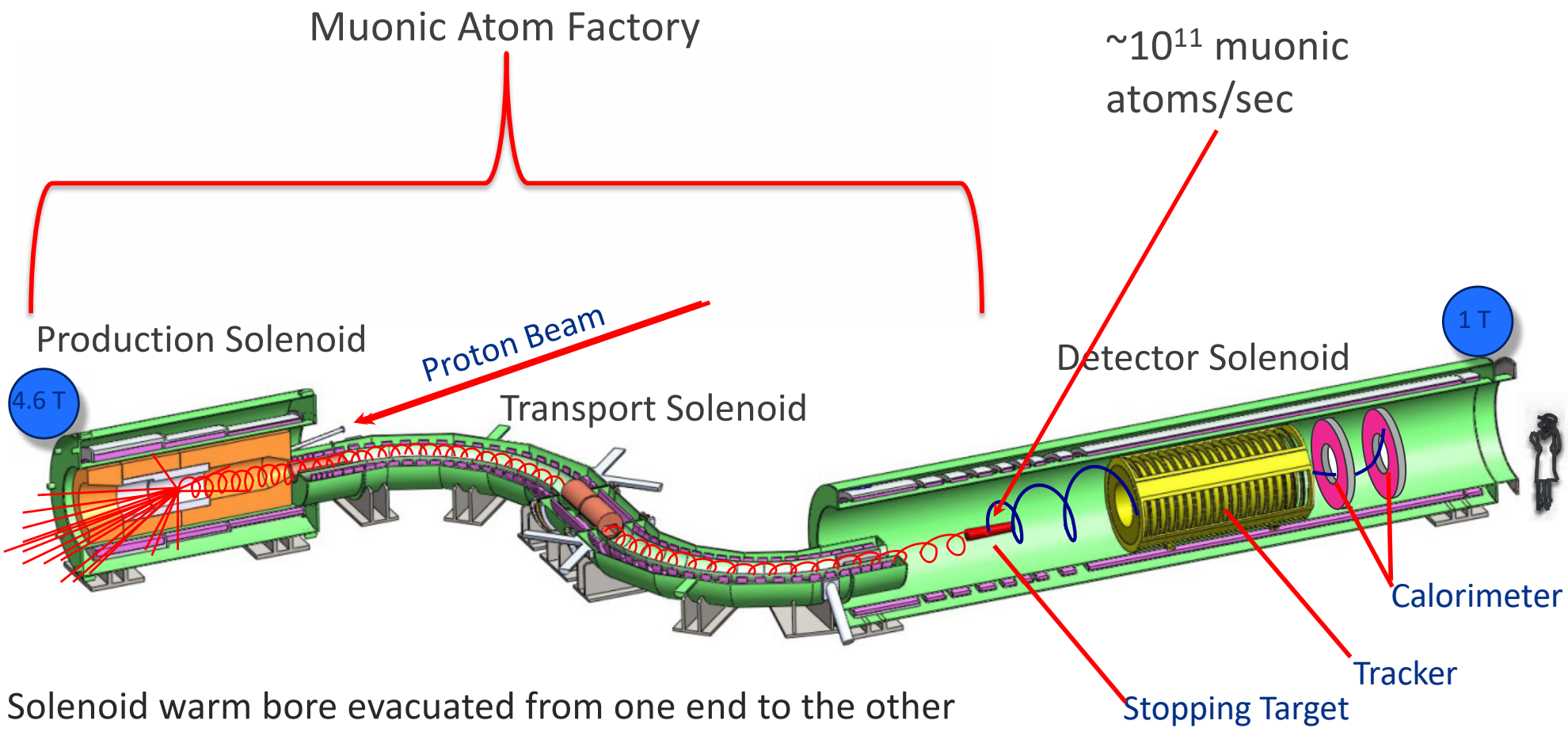
Mu2e Project scope includes

- Superconducting Solenoids
- Tracker – Straw drift tubes
- Calorimeter – Pure CsI crystals
- Cosmic Ray Veto – Scintillator
- DAQ – Streaming architecture, commercial hardware, custom software.
- Accelerator upgrades, new beamline
- New Detector Hall



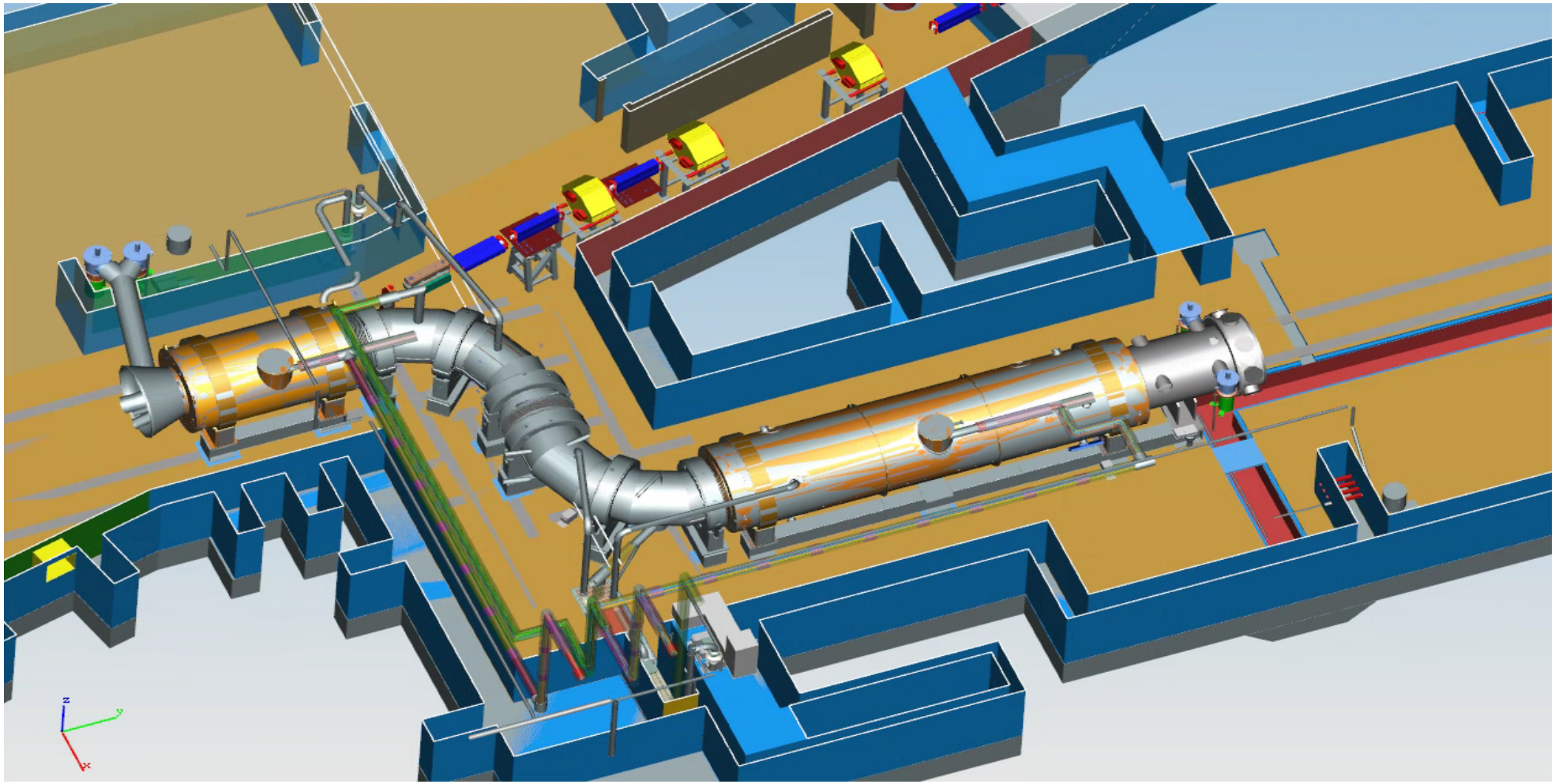
Solenoid warm bore evacuated from one end to the other

Mu2e Project Scope



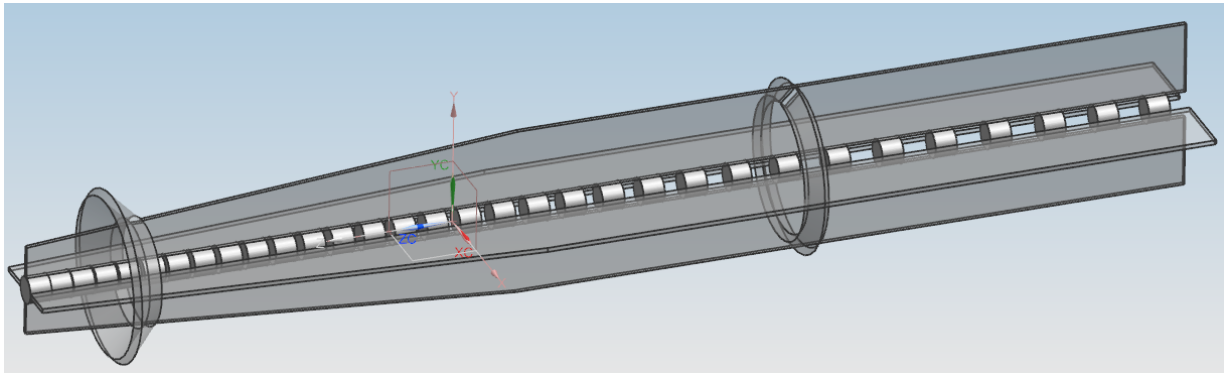
Solenoid warm bore evacuated from one end to the other

Mu2e Apparatus in Mu2e Hall



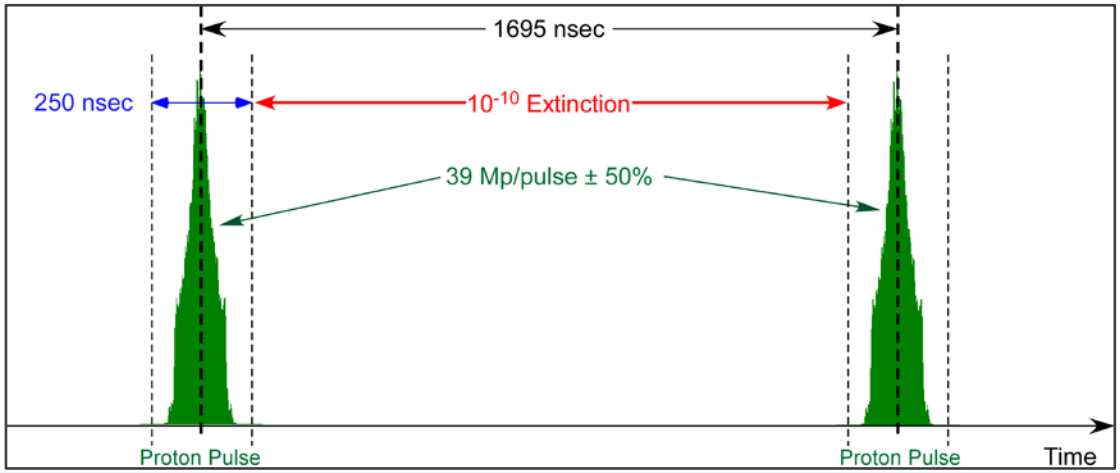
Accelerator Challenges

- Production Target lifetime
  - High Z, radiatively cooled target that optimizes stopped muon yield
  - Challenge is for target to last for a year
  - Key is to engineer a target that runs at low enough temperature to reduce impact of oxidation and creep
    - Work in progress



Accelerator Challenges

- Producing well-defined pulses of protons with nothing between pulses
  - Resonant Extraction System
    - Heat up a well defined portion of circulating beam in the Delivery Ring and deliver it down the M4 beamline to Mu2e
  - Extinction System
    - AC dipole magnets that eliminate out-of-time beam
- Both systems are extremely challenging.



Summary

- Mu2e is an exciting particle physics program with an opportunity to make an historic discovery.
- Mu2e requires unique and specific beam requirements and a challenging production target
- Success of the Mu2e Project and experiment depend on the people in this room.

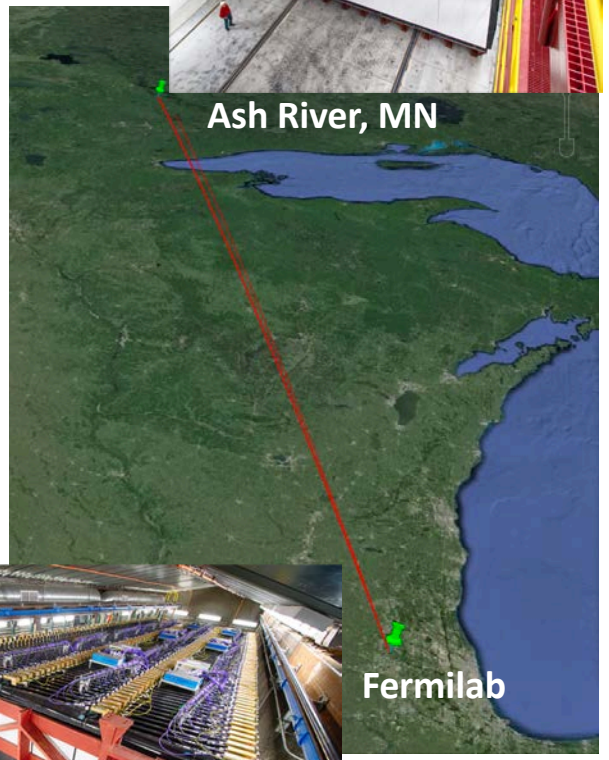
NOvA

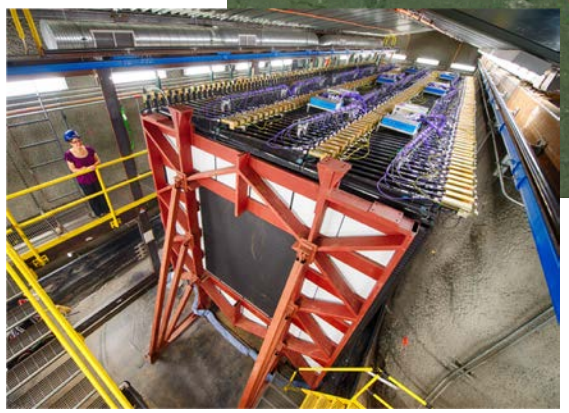
NOvA

- Study $\nu_\mu \rightarrow \nu_\mu$ and $\nu_\mu \rightarrow \nu_e$ oscillations with NuMI beam and two detectors separated by 809 km
  - Use both neutrinos and antineutrino
- Why? Neutrino masses and flavors mix.

Flavors | ν_e | ν_μ | ν_τ | vs Masses | ν_1 | ν_2 | ν_3 |

- Questions we can investigate in NOvA
  - Is ν_3 heaviest or lightest? Mass Hierarchy.
  - Is ν_3 more ν_τ or ν_μ, or equal? "Octant of θ_{23}" and maximal mixing.
  - Do neutrinos behave differently than antineutrinos? CP Violation.
  - Is there more to the picture?

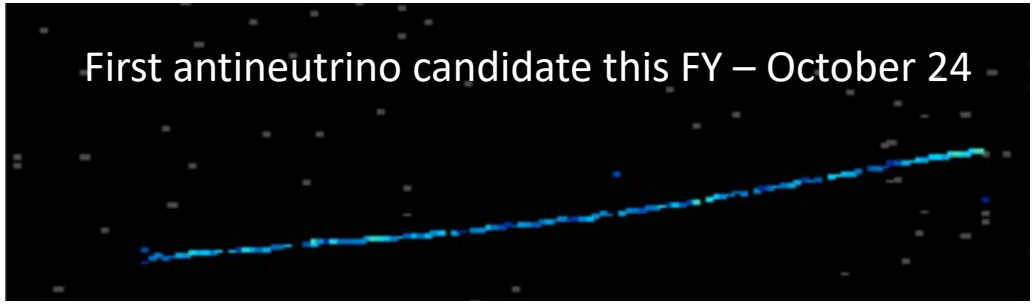




NOvA

- Approved baseline: $36x10^{20}$ protons-on-target (POT) to NuMI
- NOvA status – 700 kW to NuMI achieved in January 2017
  - 4 rounds of oscillation analyses presented, including 1st significant electron antineutrino appearance over a long baseline.

To Date: $8.9x10^{20}$ POT (14 kt-equivalent) neutrinos
$9.8x10^{20}$ POT antineutrinos

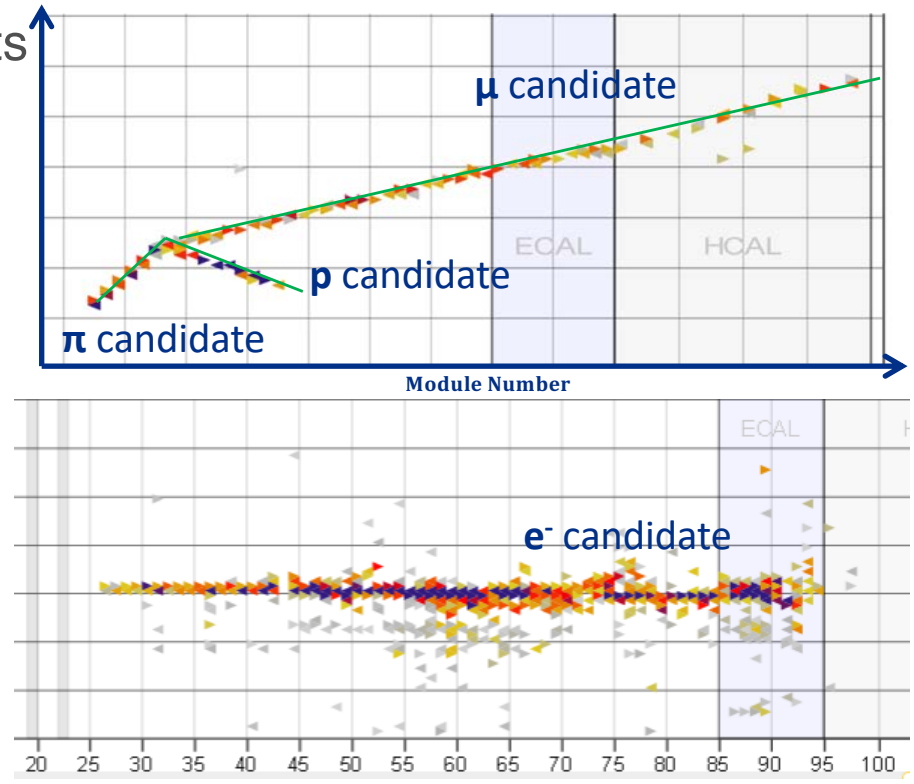


- Competition
  - T2K: μ-τ mixing, CP-violation, Mass Hierarchy (MH), ongoing
  - JUNO (reactor), ORCA/KM3NeT (atmospheric): MH mid-2020's
- Extending NOvA's reach
  - Expect to run to long LBNF shutdown in 2024
  - A set of Accelerator Improvement Projects aimed at 900+ kW
  - We hope to have $72x10^{20}$ POT by the end of NOvA
- NOvA thanks you for your dedication, hard work, and skill!

MINERvA

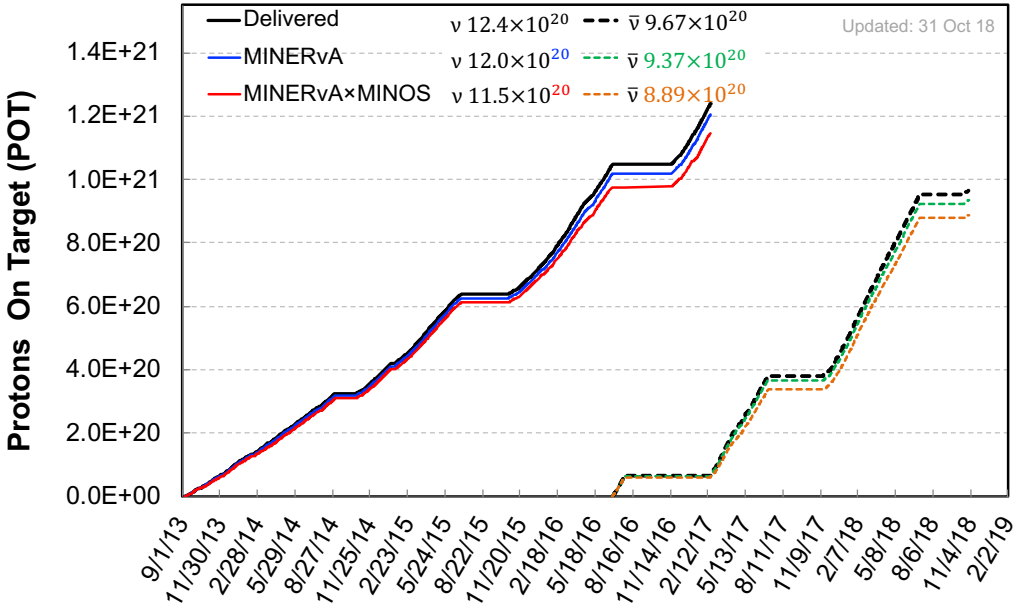
MINERvA Overview

- Running on-axis at NuMI since 2010
- Motivation:
  - Oscillation experiments like NOvA and DUNE measure neutrino oscillations by observing neutrino interactions
  - MINERvA makes precise measurements of neutrino interactions, so we can be sure that what NOvA and DUNE measure are neutrino oscillations, not neutrino interaction details
- MINERvA's Gozal:
  - Measure neutrino and antineutrino interactions
    channel by channel on many nuclei to make the best model of neutrino interactions
  - Develop analysis techniques for DUNE
- 25 Publications and counting

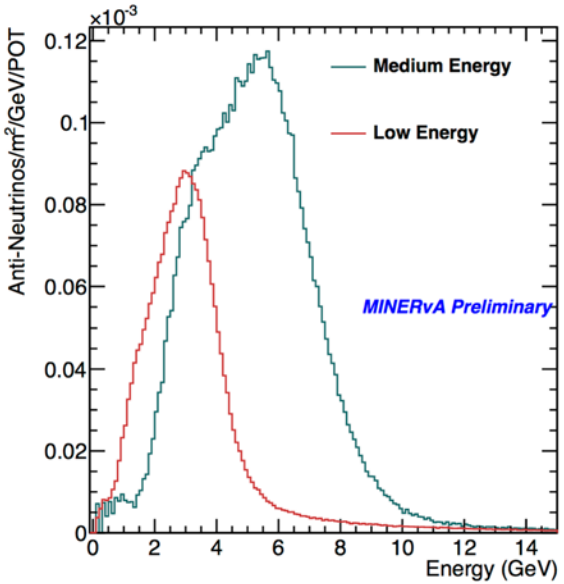


MINERvA's NOvA-Era POT Request

- 12E20 POT in each of neutrino and antineutrino mode…
- We have all the neutrino data we requested
- We already have 9.6E20 POT in antineutrino mode



Day in the Medium (6GeV) Energy Run



Huge increase in statistics from Low Energy (<2013) Antineutrino Data Set:

THANK YOU!

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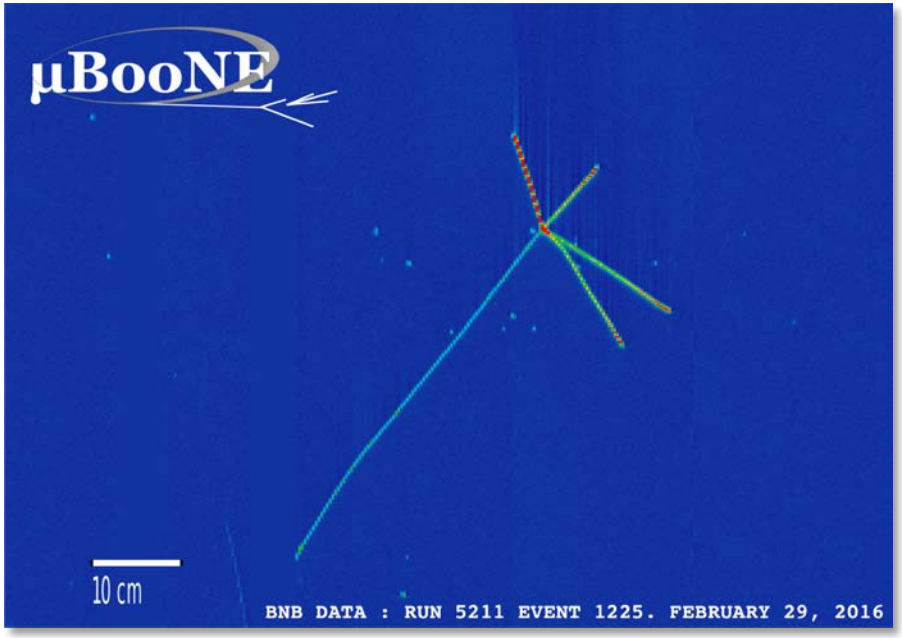
MicroBooNE, ICARUS, SBND

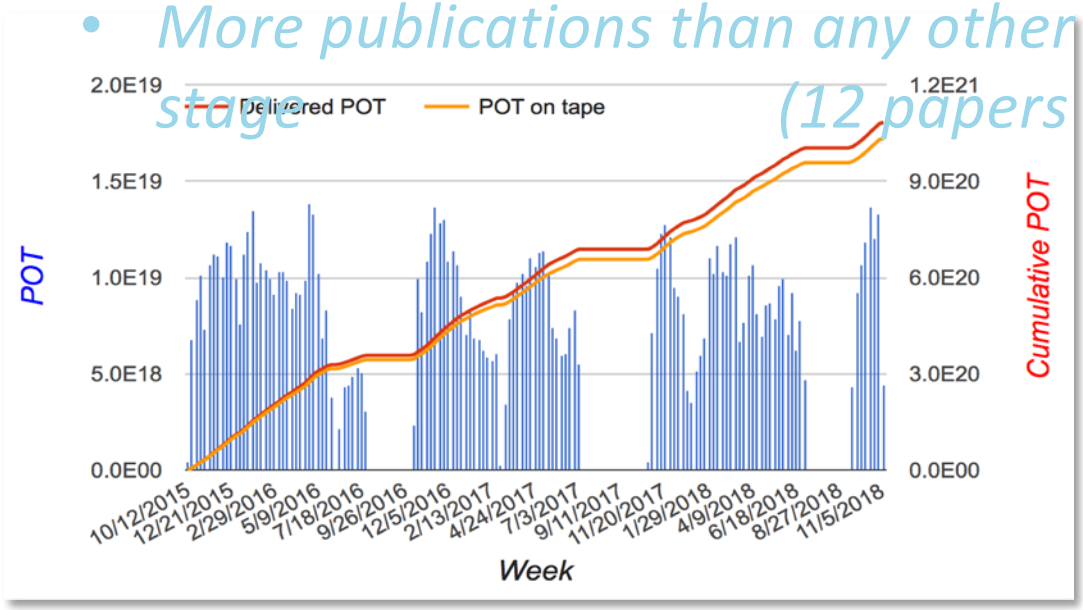
MicroBooNE

- 1st large scale LAr TPC in the U.S.
- Three main goals:
  - Understand what MiniBooNE observed → needs lots of ν's!
  - Measure low energy ν-argon interactions for the first time
  - Push the technology so can scale to DUNE sizes
    - *non-evacuated vessel*
    - *long drift distance (2.5m)*
    - *cold electronics*
    - *calibration laser*
- A lot of firsts, critical work for DUNE



Beam to MicroBooNE

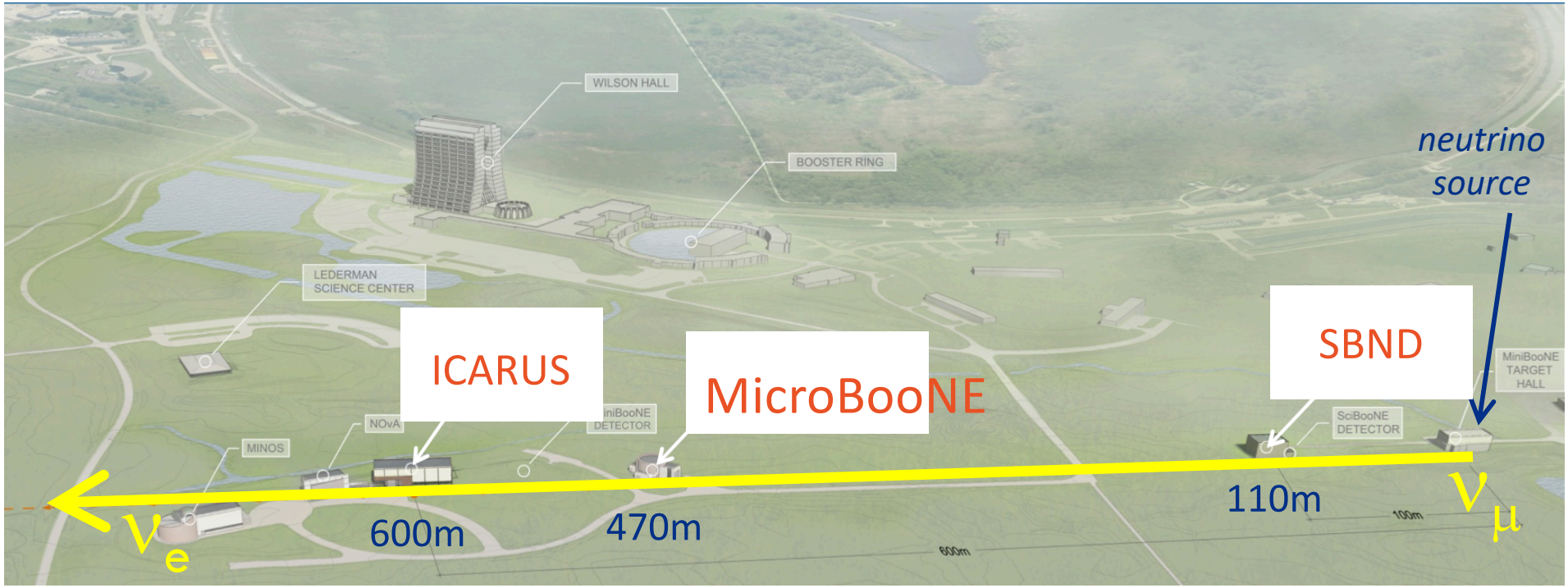
- Detector has been running extremely well for 3 years, >95% uptime
- Collected 10.4×10^{20} POT (~80% of total neutrino beam request)
  - *Remarkable that complex is supporting MicroBooNE, NOvA, g-2*
  - *This is the place to do neutrino physics*
- Learning a lot; large, very dedicated team looking at this data
  - *174 collaborators including 52 grad students + 44 postdocs*
  - *More publications than any other FNAL ν experiment at this stage (12 papers + 28 public notes)*



- Please keep the excellent beam coming to BNB!
- Big decision to make this summer whether to request more ν running or move into an R&D mode

Short-Baseline Neutrino (SBN) Program

- MicroBooNE = Understand what MiniBooNE saw
- SBN = Definitive search for additional type(s) of neutrino(s)



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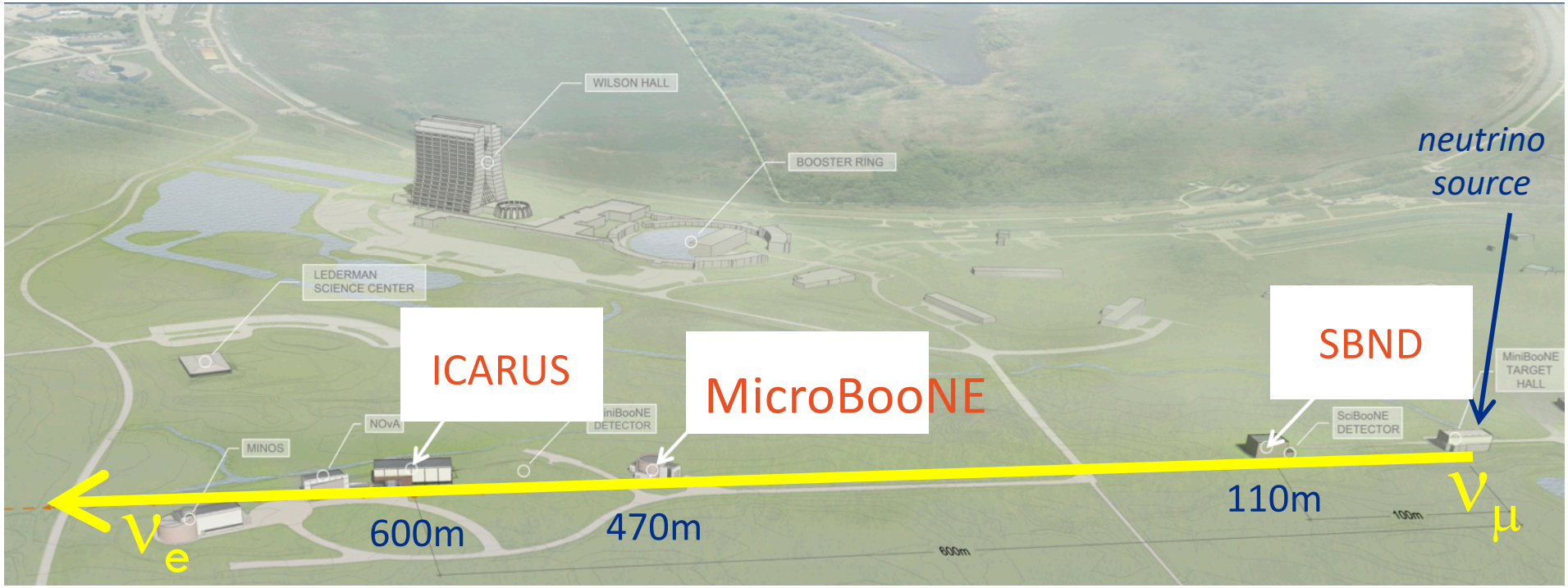

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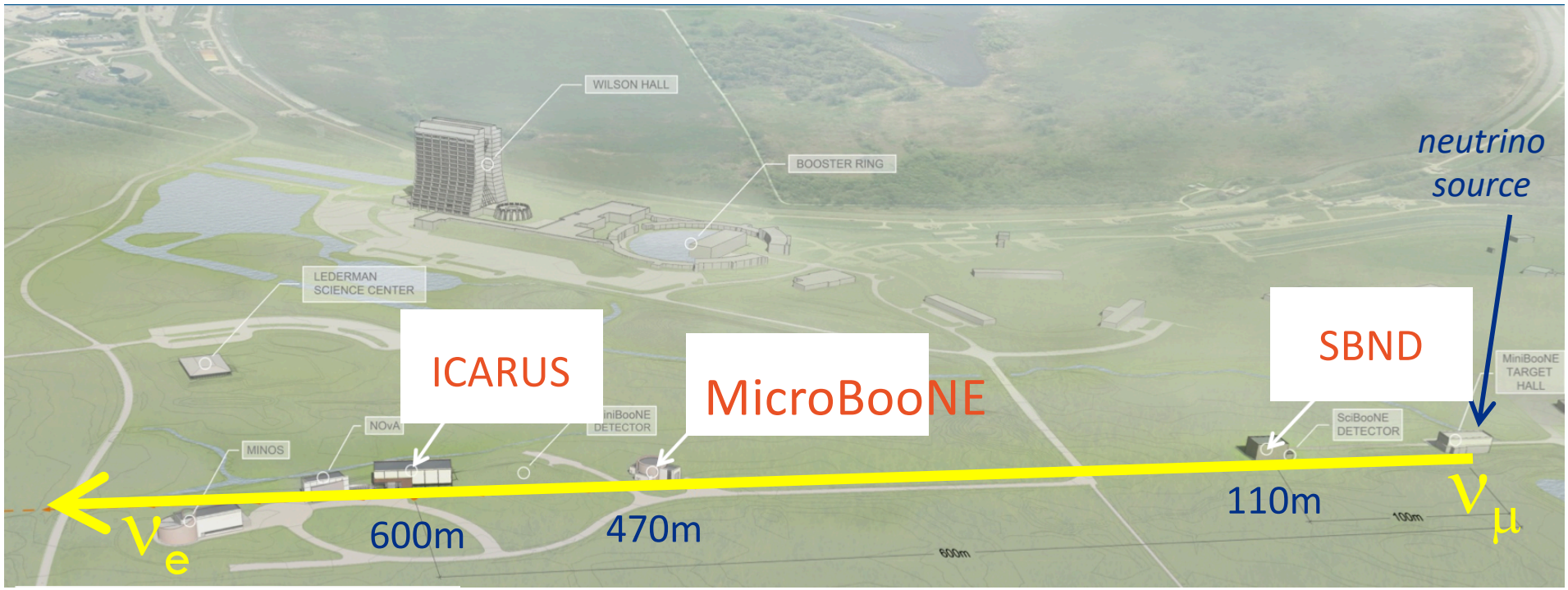

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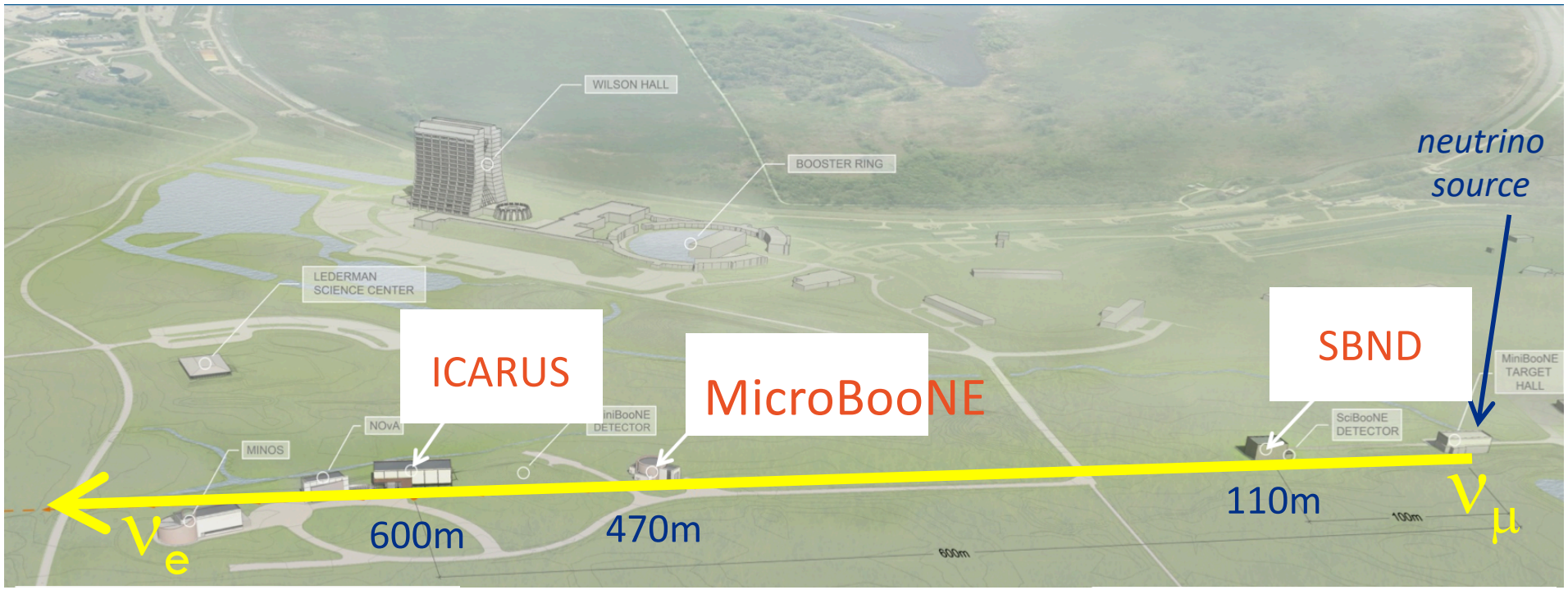

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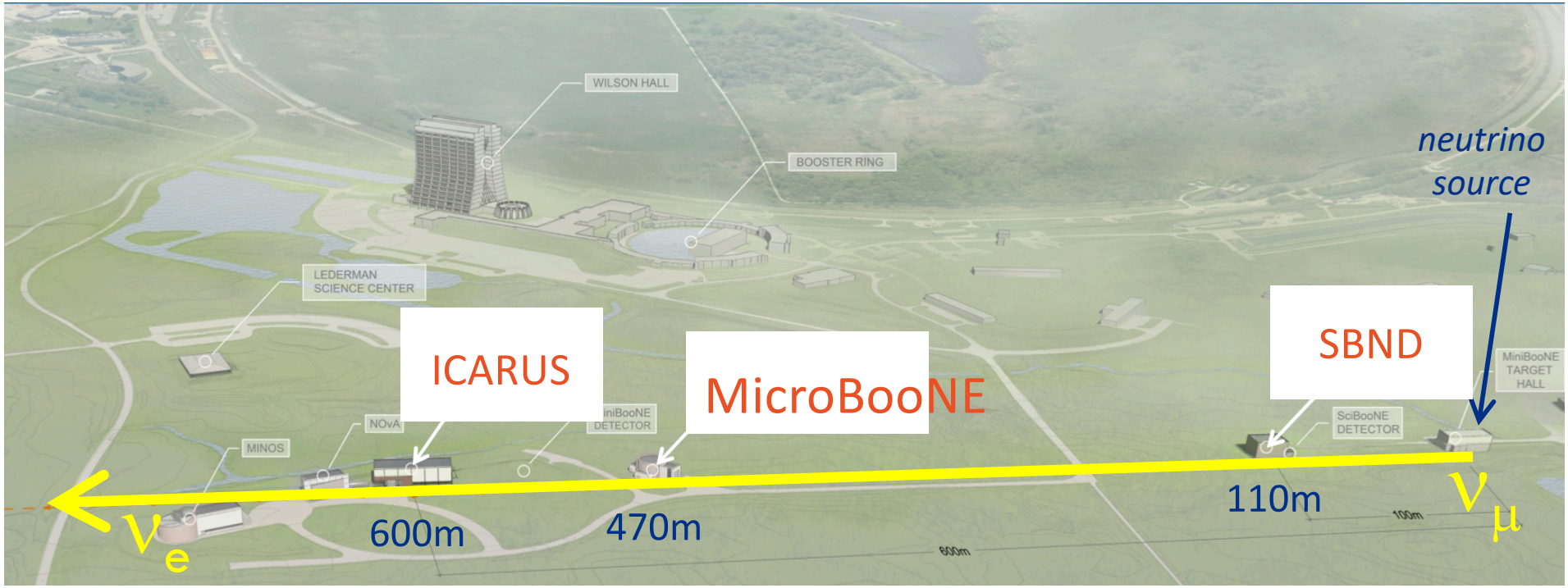
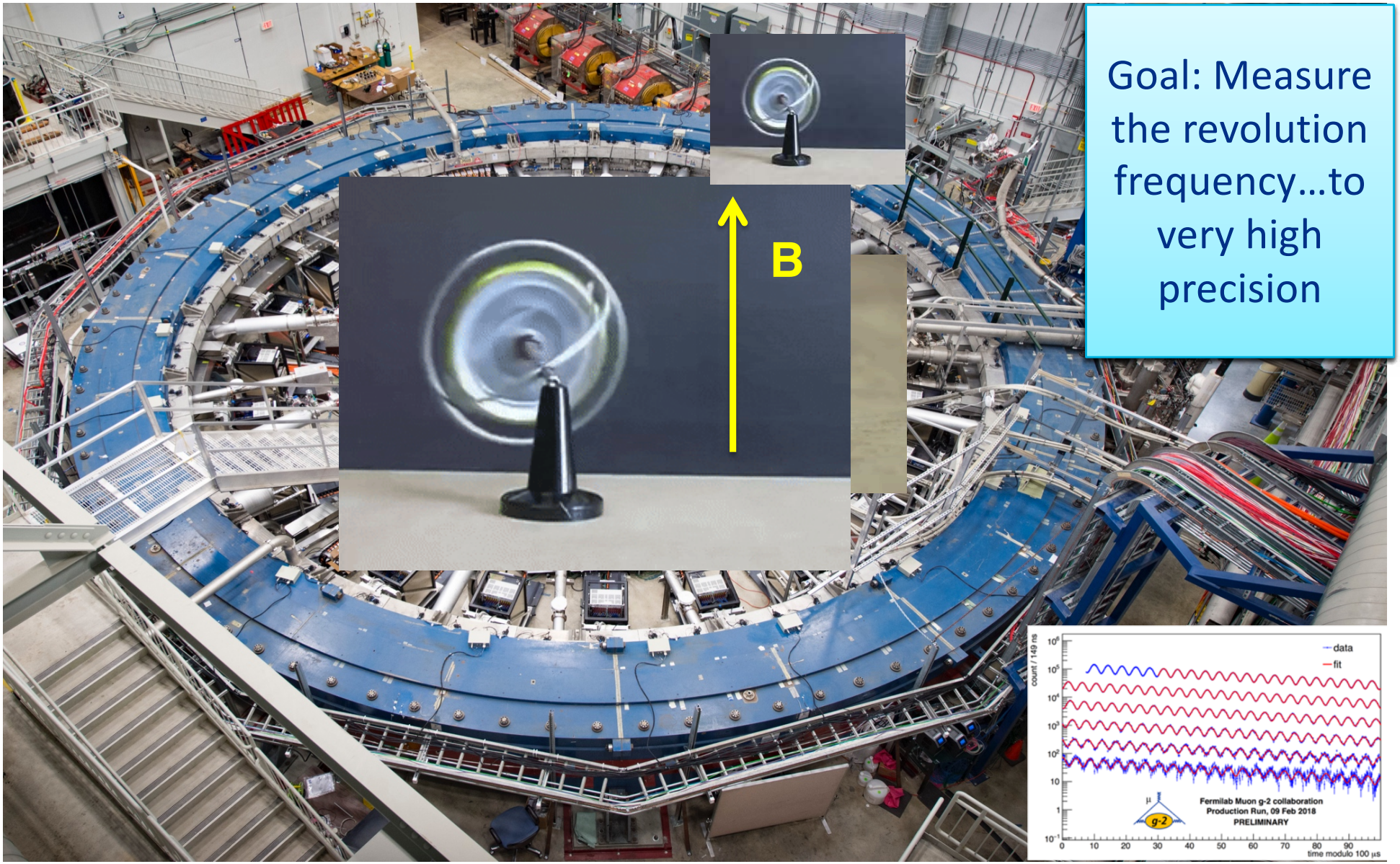


- 1st time have strung together a series of LAr TPCs in the same beam
- Competition from reactor ν, astrophysical ν, cosmology
- If observe evidence for a sterile neutrino, this is a game changer

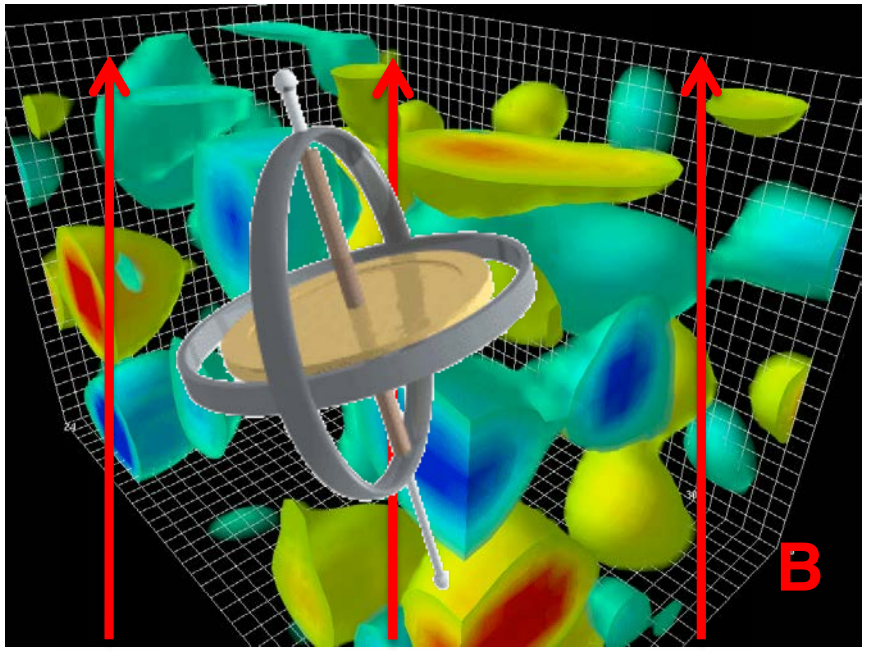
g-2

Muon g-2 studies the motion of muons in a magnetic field



Why?

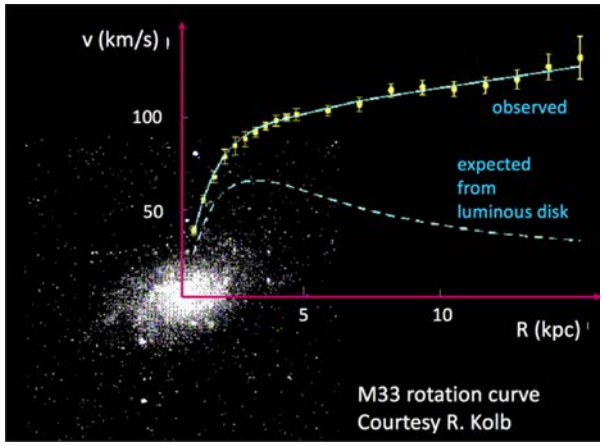
Image Credits: Derek Leinweber



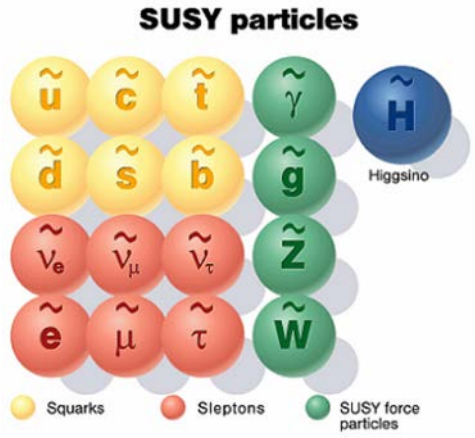
- Turns out no particle in the universe is ever truly alone
- Every type of particle we have ever discovered can mysteriously blink in and out of existence
- Changes the precession frequency

By measuring the frequency to incredibly high precision we are really searching for the tell-tale sign of new particles and forces!

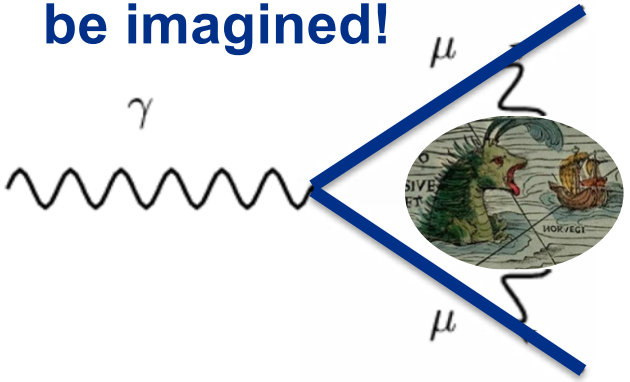
Dark matter!



SUSY!

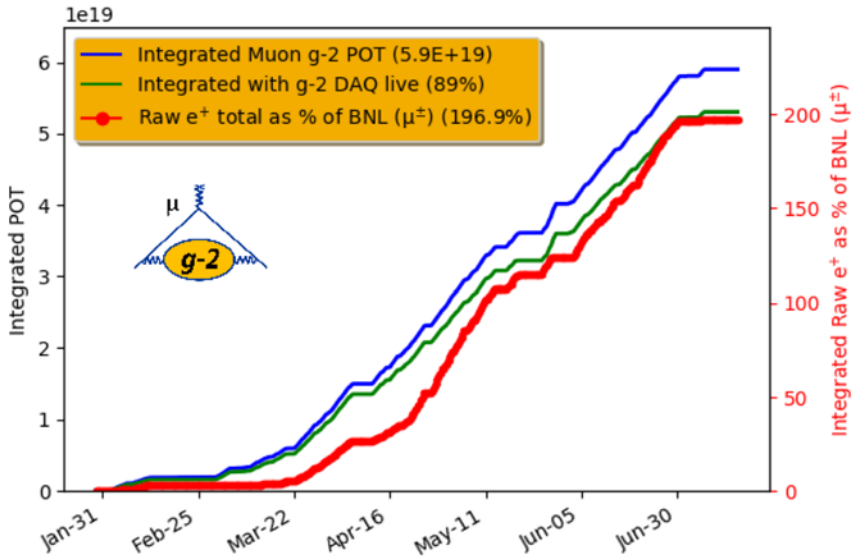


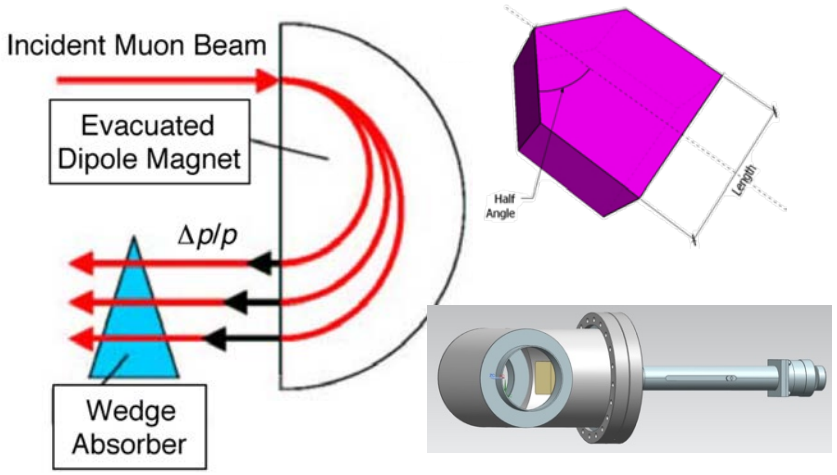
Monsters yet to be imagined!



FY19 beam delivery goals

- High precision requires many muons
  - 20x more than ever before (BNL)
  - 200,000,000,000 of them!
- Collected 2x BNL g-2 in FY18 → aiming for 8-10x BNL in FY19
  - Need ~1.3e20 stable POT delivery
  - Also need 50% more muons/POT



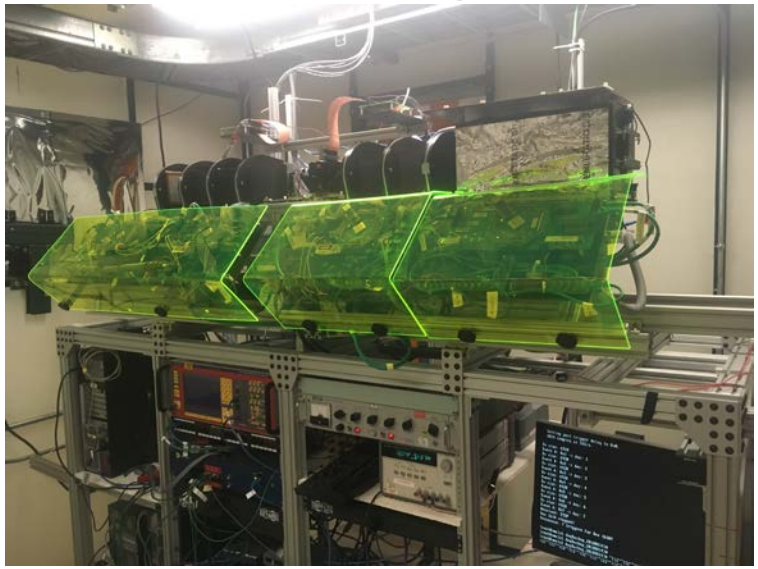


Major AD contributions to muons/POT…wedge absorbers and in-ring kicker upgrades!

Fermilab Test Beam Facility

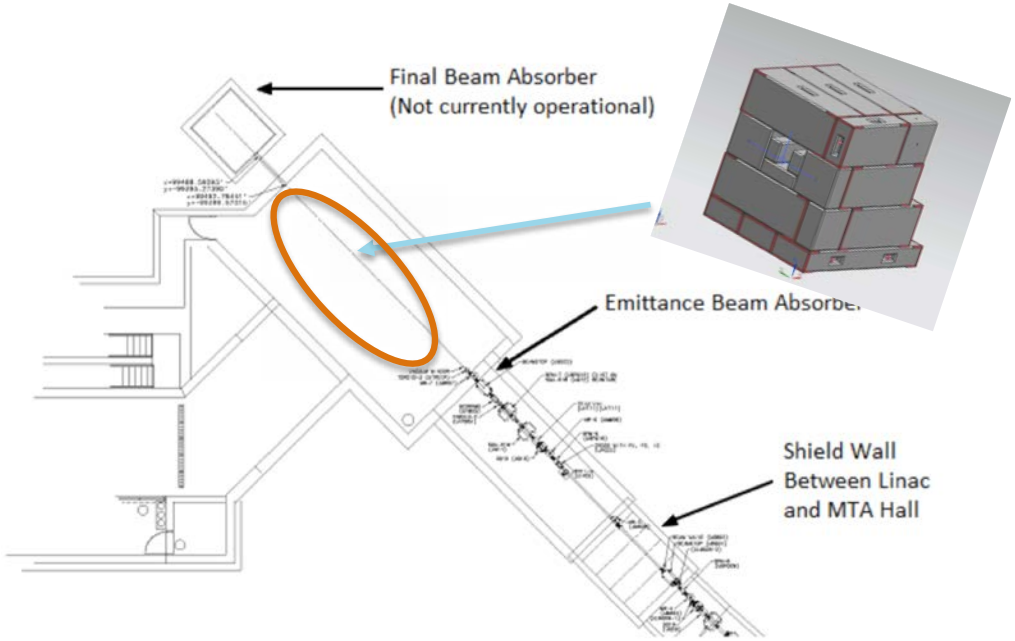
Test Beams and Irradiation Facilities

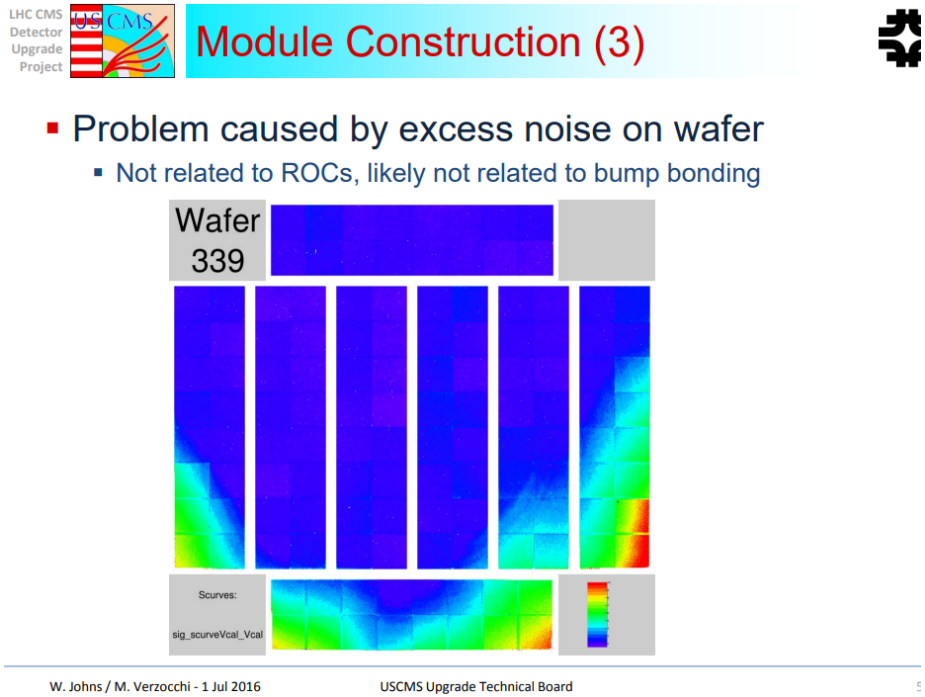
- Test Beams are critical to the lifecycle of a detector.
  - Funding will often hinge on results
- FTBF is one of the highest energy test beams in the world.
  - HL-LHC testing is critical at the test beam
  - Provides charged hadrons
- Users are often under huge time pressures
  - They only get 1 week of beam, disruptions can be huge



Irradiation Test Area

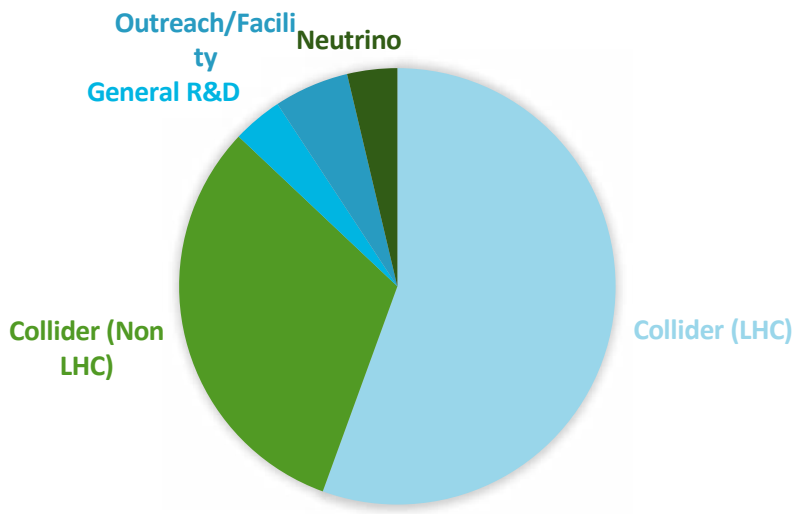
- How detectors work after being in a high radiation environment is critical to design choices.
- Irradiations can also fix issues with detectors
  - Example: FPIX
- Most irradiation facilities limit time for HEP users



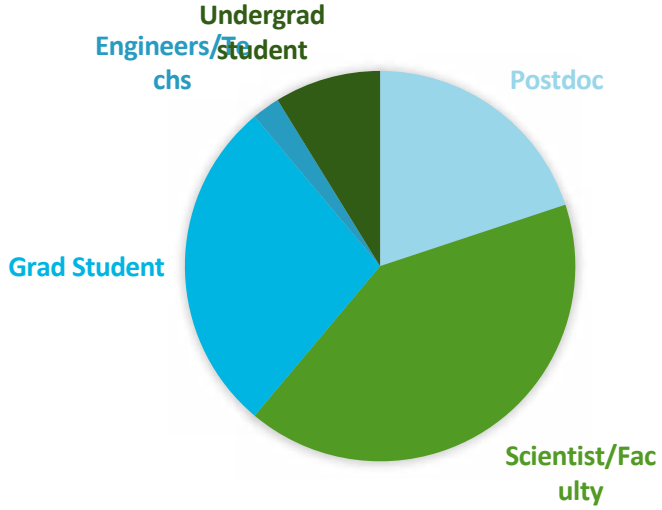


Test Beam Last Year

- 20 experiments last year
  - CMS, ATLAS, Mu2e, sPHENIX, EIC R&D, SBND, LArIAT
- 216 users at the test beam
- 4 journal publications, numerous posters and conference proceedings
- EDIT Detector School
- **FY18 USER GROUP BY RESEARCH FOCUS**



FY18 USERS BY JOB TYPE



How we can work together

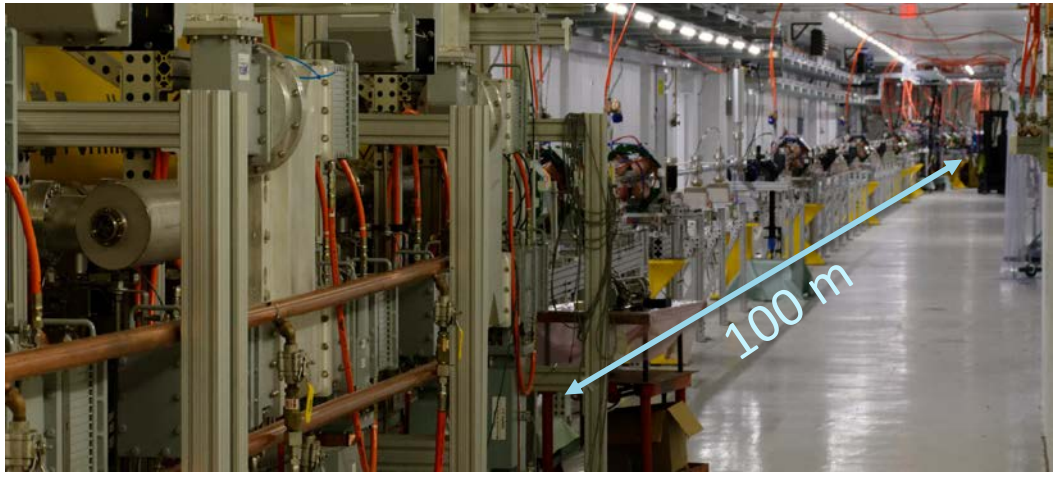
- Ask questions – people love to talk about their work
  - Users are sometimes bringing in state of the art detectors that are seeing beam for the first time
- Communication!
  - FTBF elog: http://dbweb6.fnal.gov:8080/ECL/test_beam/E/index
  - We also read the MCR elog, so many and concise entries are very helpful to us!
- We are happy to have visitors at any time!!

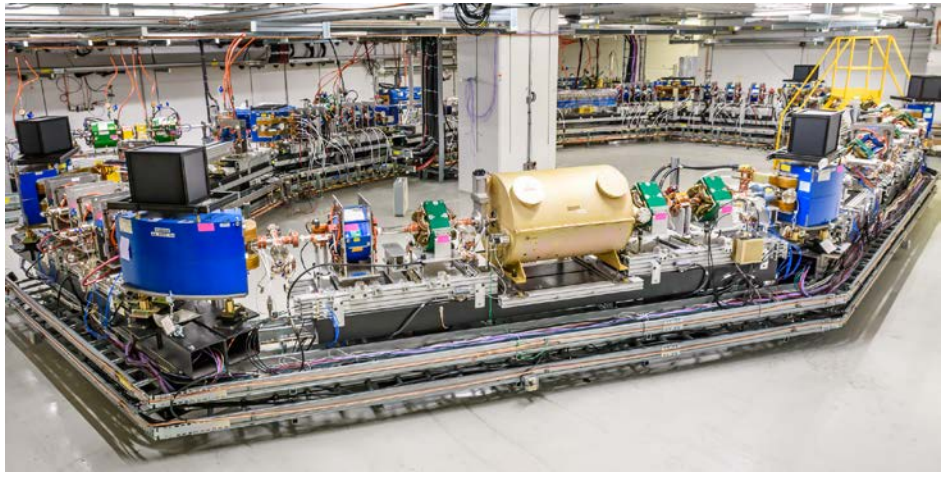
IOTA/FAST

Integrable Optics Test Accelerator
Fermilab Accelerator Science and Technology facility

IOTA – one of a kind particle storage ring designed and built specifically to host novel accelerator science experiments with *both **electrons** and **protons***.

The IOTA/FAST facility offers a flexibility that can be useful to a wider community – above and beyond the needs of high-energy physics.





FAST e- Linac – ILC R&D, IOTA injector
11/15/17 accelerated beam to 301MeV
Record ILC-type CM acceleration 255MeV

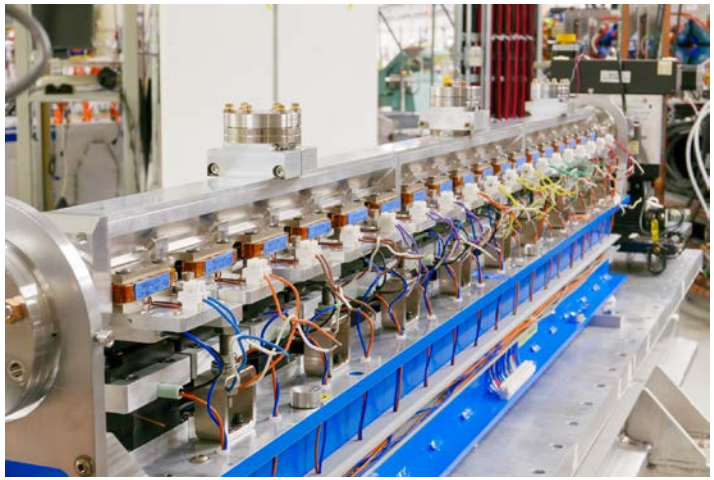
IOTA
8/21/18 first beam at 47Mev
10/16/18 beam circulation at 100MeV

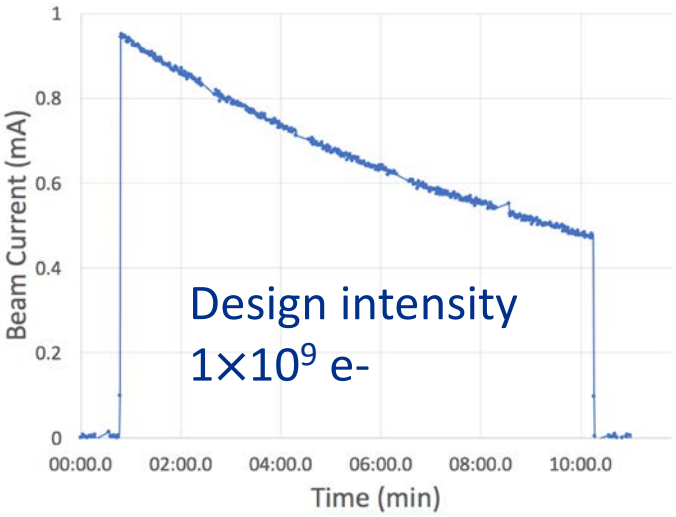
IOTA Research – Science of Intense/Bright Beams

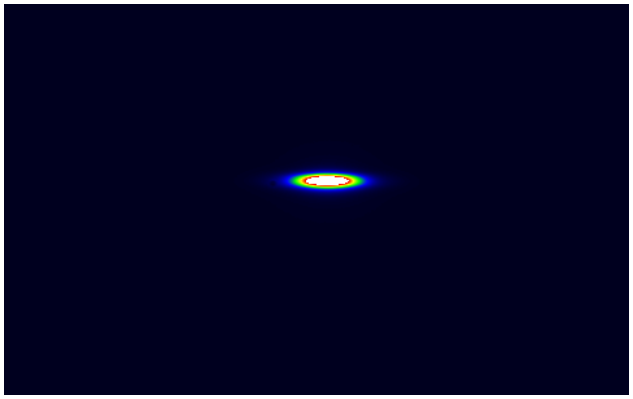
Nonlinear Integrable Optics - novel concept in beam dynamics centered on beam brightness for next generation machines.

The goal is to improve stability and reduce losses in synchrotrons.

1. Implementation with **special magnet** – **e- beam studies** this year







2. Implementation with **electron lens** – FY20
3. Research with **proton beams** – FY21 and beyond

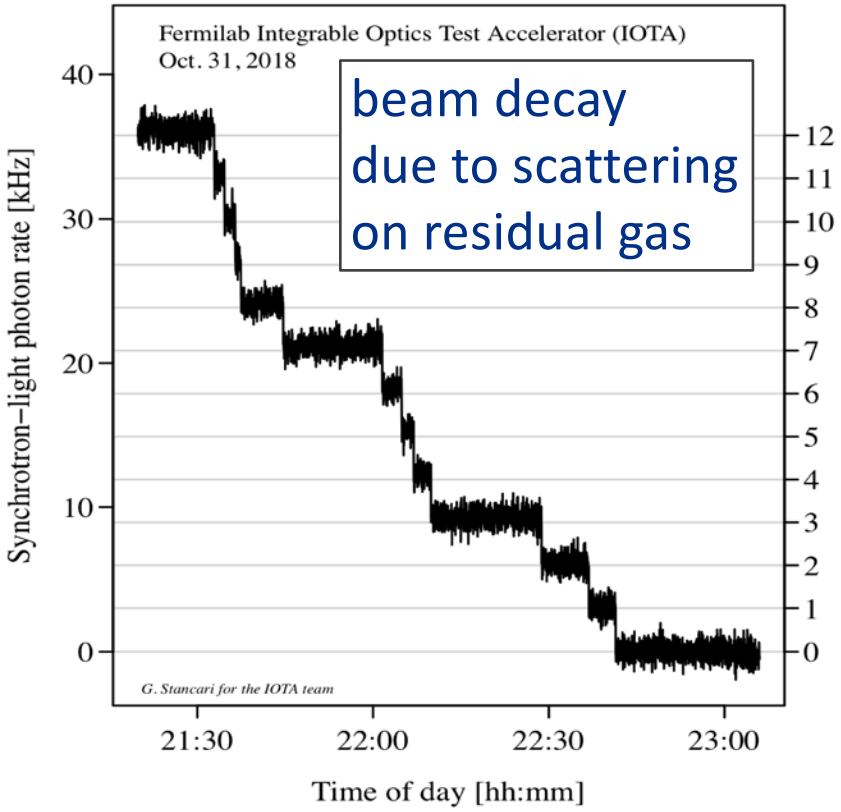
Optical Stochastic Cooling can increase cooling rates by orders of magnitude for future colliders (HEP, NP) – FY19

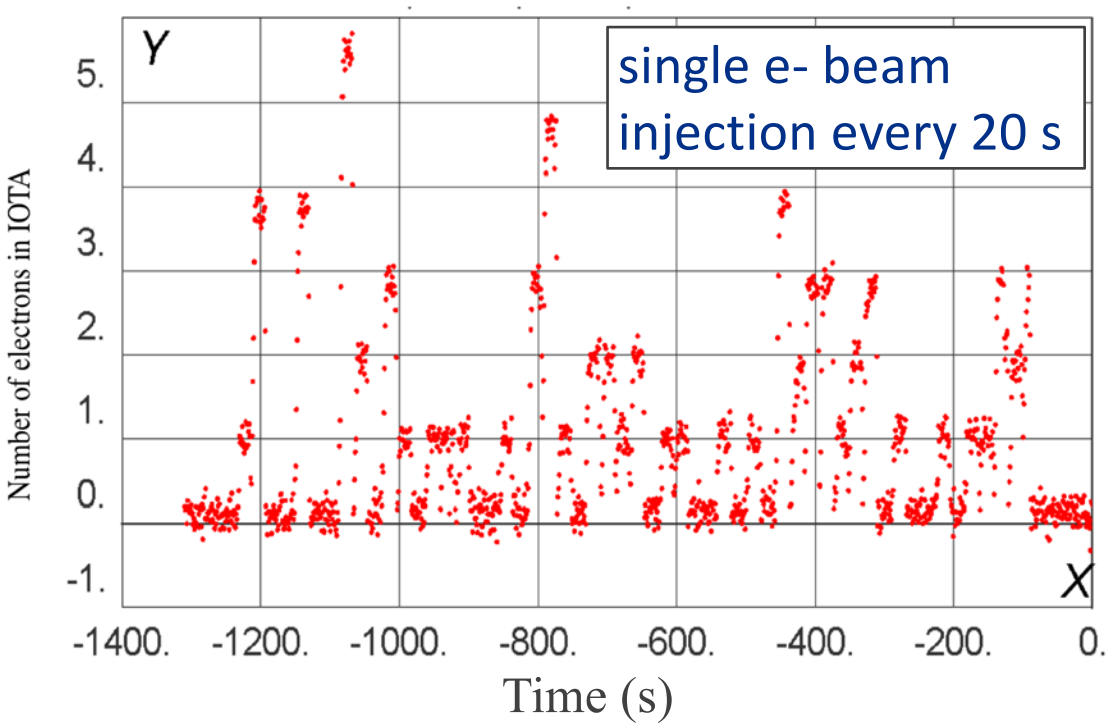
IOTA Research – Quantum Science

IOTA can store a **single relativistic electron** for long periods of time (~10 minutes).

Relatively high particle energy enables observation of photon emission

- Opens way to a variety of quantum experiments





Questions

Questions

- People with school kids usually stay home on Veterans Day, and some technicians are already leaving after 3PM. What is the rational for choosing such data/time for this meeting?
  - Most of the all-hands were scheduled for the 3-4 Monday time slot in the weeks following the Directors all-hands. This was our assigned time.

- What is the official AD goal for MI power on target for 2019?
  - For FY19 NOvA goals, the complex needs to consistently deliver ~700kW

Questions

- It feels that most of new people are coming to AD departments by being hired to MCR and then transferred. Is it correct?
  - New hires on slide 6. Our operators are in demand lab-wide
- Apart of FAST/IOTA, percentage of postdocs in AD is very low. Is it intentional?
  - We are working to increase the number of RA's positions in AD
- In my mind, some of support departments are less capable now (understaffed, lost expertise) than they were in the Tevatron era. Would AD management agree with this statement?
  - ~370 FTE's in AD now – down ~180 FTE's from Tev peak
  - I like our team, and as our experienced people retire, we need to work hard to train new people – who also bring new skills

Questions

- Are there any foreseen changes to AD's Vision & Mission?
  - Fermilab's Accelerator Division operates, maintains, and improves the laboratory's accelerator complex, beam lines and beam targets.
    - Our vision is to build and operate megawatt particle beams that will enable the science goals outlined in the 2014 Particle Physics Project Prioritization Panel (P5) report.
  - Our mission is to drive scientific discovery by:
    - delivering particle beams for scientific research;
    - conducting accelerator physics research;
    - designing and building accelerators to extend the scientific reach of existing facilities.

Questions

- As the lab is doing everything on a project basis now, what are the plans for internal development and upgrades that are necessary but not in project scopes?
  - AIP's – minor construction projects (meaning less than $20M)
  - "Campaign" towards 900kW capability
  - Modernization review
  - Initiatives – Controls, Target Materials Science, Robotics
- Besides deliverables to DOE, what are the Division (especially management) goals in the next 24-36 months; what can we do individually to ensure collective success?
  - Reflected in our top 5
  - Do excellent work safely, succession plan and share knowledge
  - Support projects and each other, stay positive in demanding times